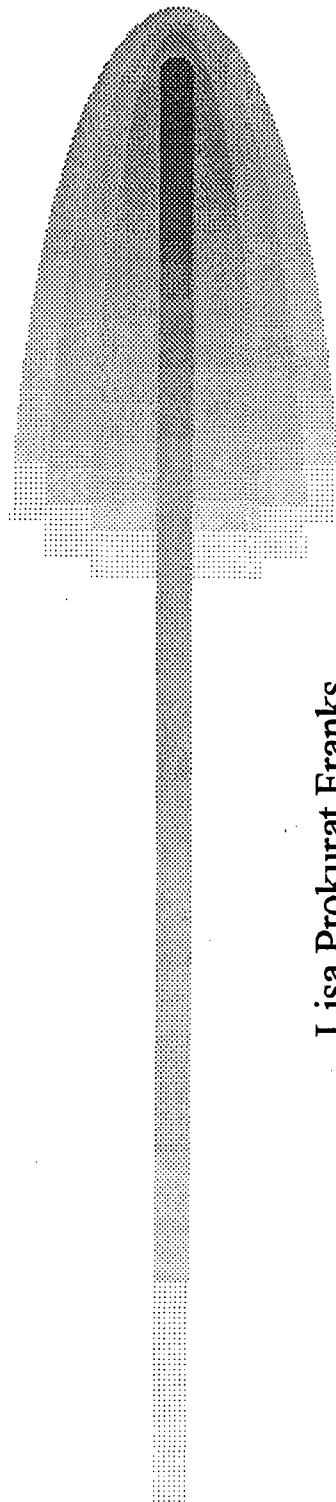


The Effects of Colloidal Processing on the Densification of Titanium Diboride (TiB_2) - Alumina (Al_2O_3) Composites



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Abstract

Titanium diboride/Alumina ($\text{TiB}_2/\text{Al}_2\text{O}_3$) powders produced using self-propagating high-temperature synthesis (SHS) can be hot pressed into armor tiles that exhibit superior resistance to penetration as compared to TiB_2 , SiC , B_4C or Al_2O_3 .¹ As with other advanced ceramics² however, difficulties in processing $\text{TiB}_2/\text{Al}_2\text{O}_3$ arise from the inability to reproduce specimens having identical microstructure and properties. Since the SHS powders are available commercially, the interactions between TiB_2 and Al_2O_3 have been analyzed with respect to their colloidal properties, as measured by their respective zeta potentials, density, volume fraction, and particle size. A comparison of colloidal properties, green and sintered densities and microstructure of Composite SHS $\text{TiB}_2/\text{Al}_2\text{O}_3$ and SHS TiB_2 with commercially available Aluminas has been completed. Although *SuspensionStability*[©] predicts the colloidal behavior of SHS TiB_2 in Alumina, the SHS Composite powders seem to be insensitive to colloidal processing, and the continuous microstructure associated with penetration resistance is predominantly characteristic of SHS Composite $\text{TiB}_2/\text{Al}_2\text{O}_3$ starting powders.

Z

References

- [1] K.V. Logan, "Elastic-Plastic Behavior of Hot Pressed Composite Titanium Diboride/Alumina Powders Produced Using Self-Propagating High Temperature Synthesis," Georgia Institute of Technology, September 1992
- [2] B.A. Wilson and M.J. Crimp, "Prediction of Composite Colloidal Suspension Stability Based upon the Hogg, Healy, and Fuerstenau Interpretation," *Langmuir* 1993, 9, 2836-2843

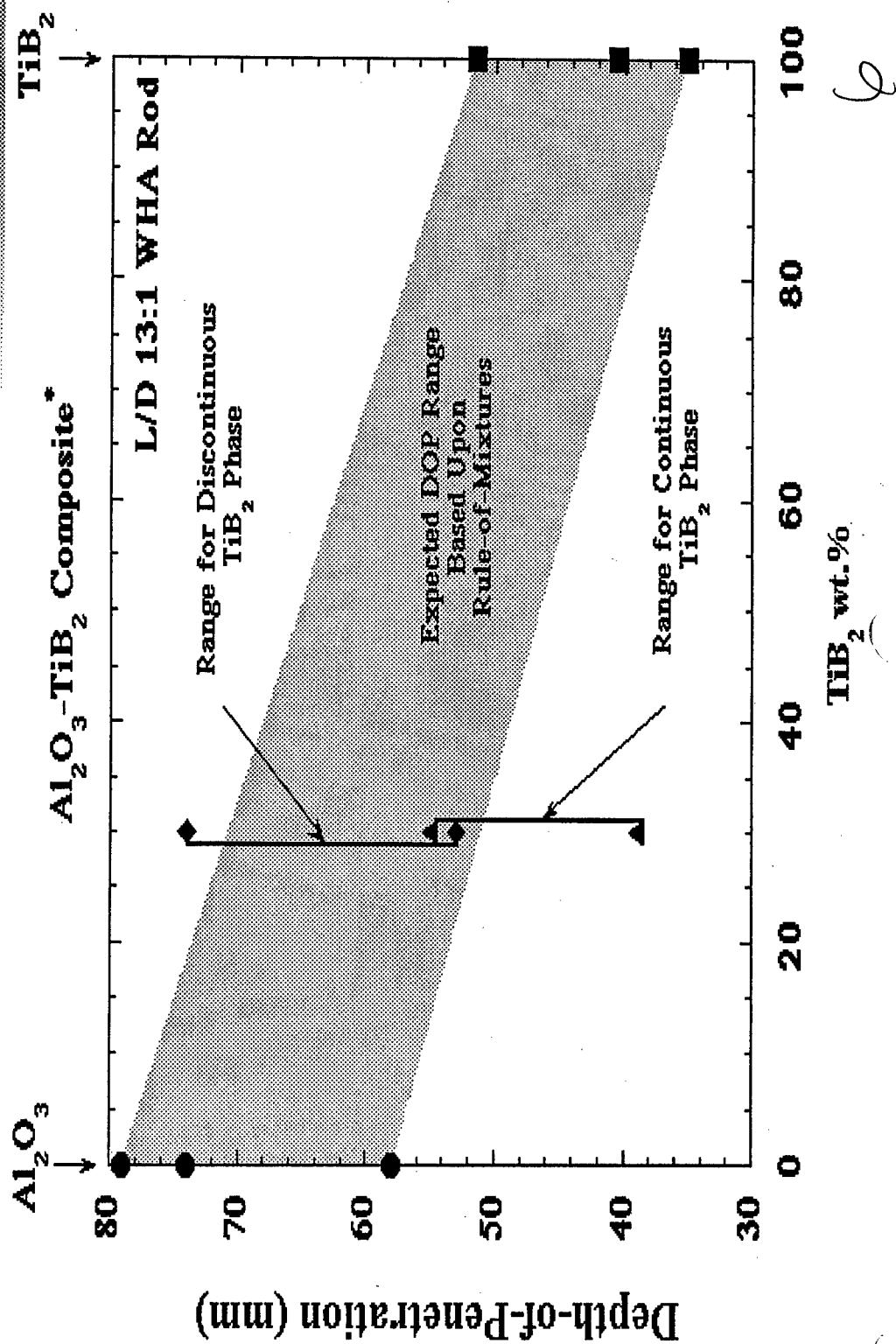
Why Investigate the Titanium Diboride - Alumina Ceramic Composite System for Vehicle Protection?

- Penetration resistance similar to pure TiB₂ at lower cost
- Performance better than expected by Rule-of-Mixtures suggesting unique, exploitable failure mode(s)
- Opportunity to optimize microstructure to decrease range of variation in performance and increase penetration resistance
- Commercial availability of SHS powders enable investigation of other processing routes

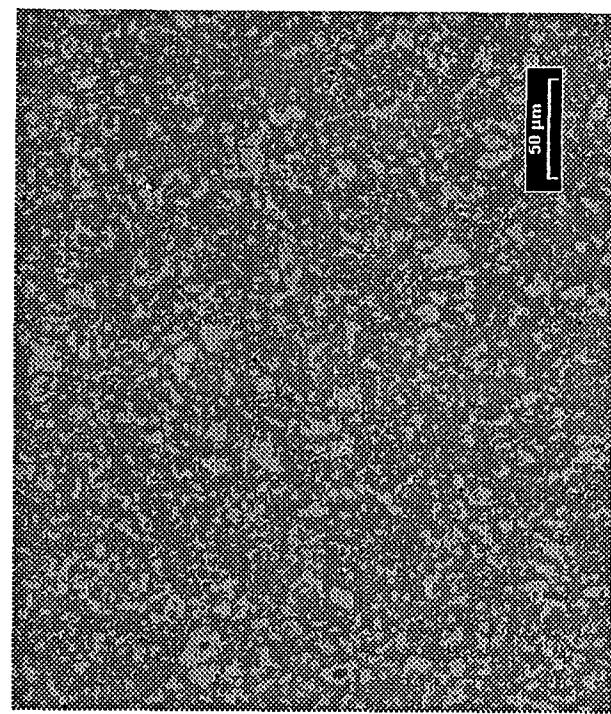
Future Work

- Quantify the sintering parameters that optimize microstructure
- Evaluate and scale-up processing to produce armor targets for evaluation against small and medium caliber threats
- Shots on 4" targets scheduled to begin 9/00

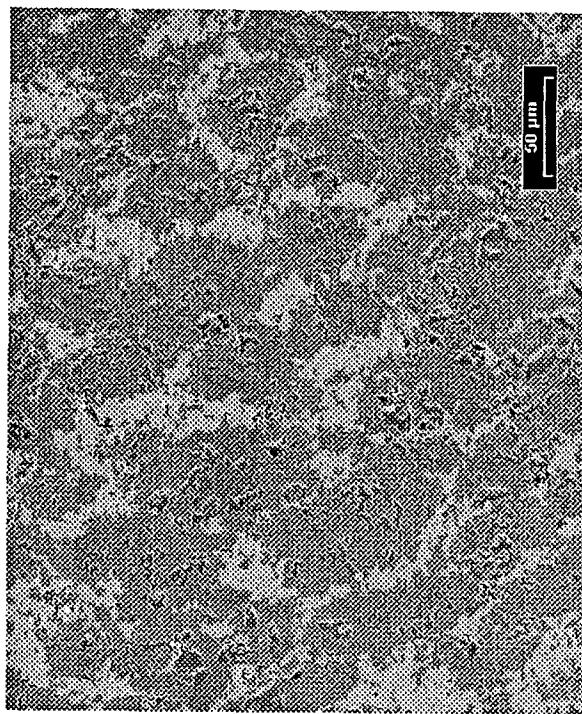
Depth of Penetration Vs. Composition



Microstructures



Discontinuous

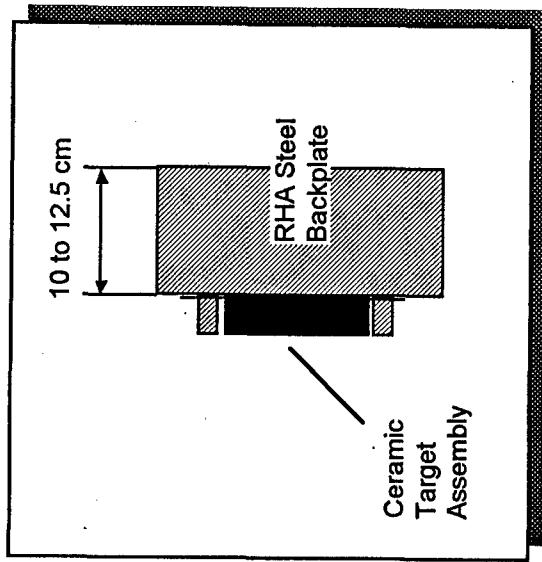
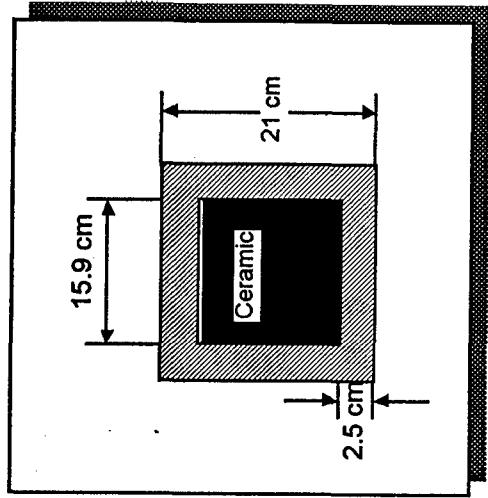
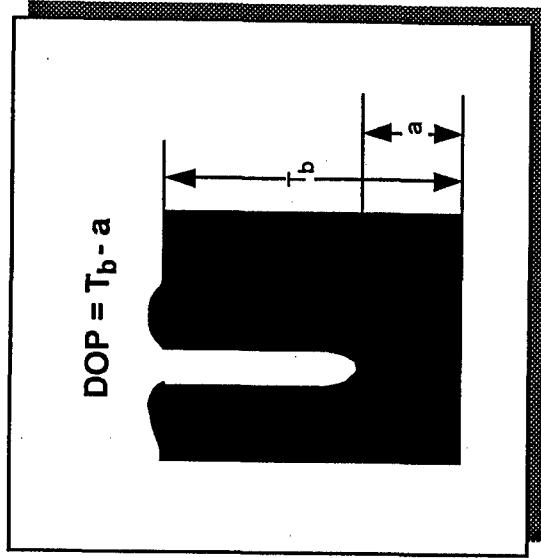
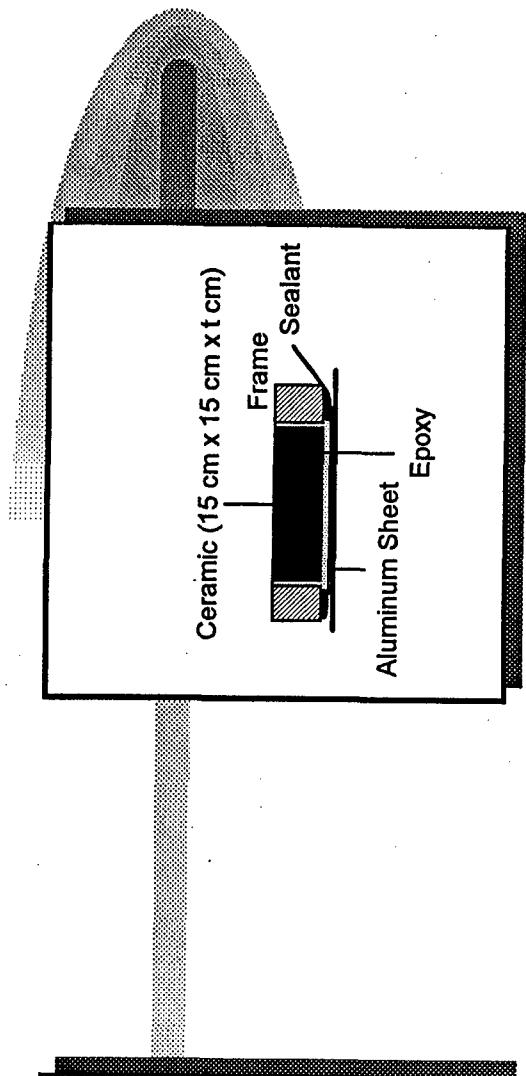


Continuous

Superior Penetration Resistance

TiB_2 (light areas)/ Al_2O_3 (dark areas)

DOP Target Assembly



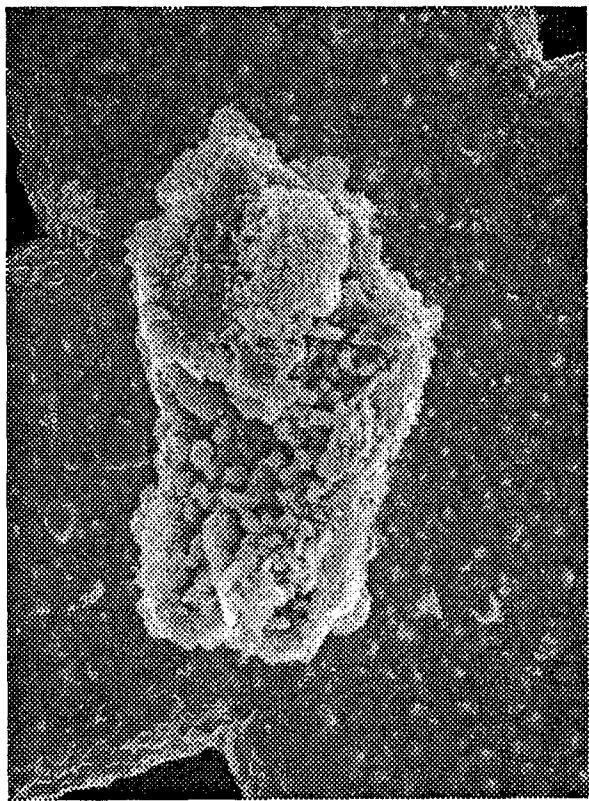
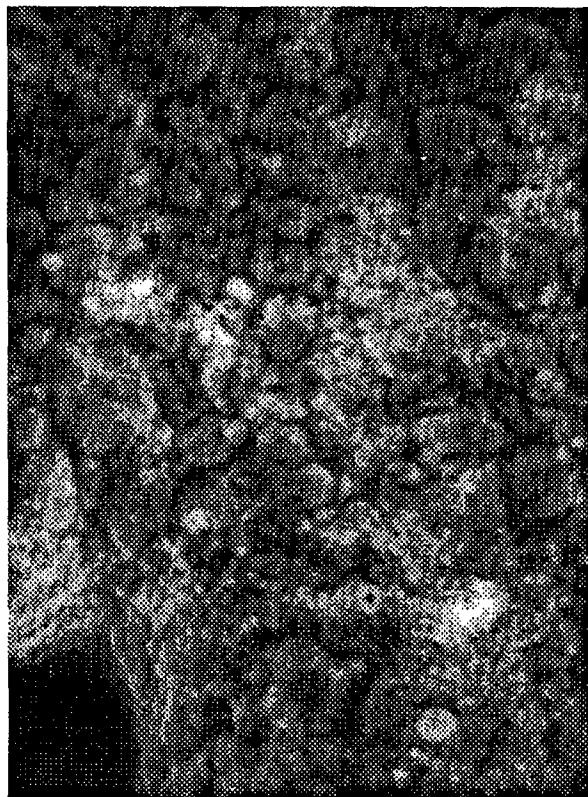
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*SHS Composite Titanium
Diboride (TiB_2) - Alumina (Al_2O_3)*



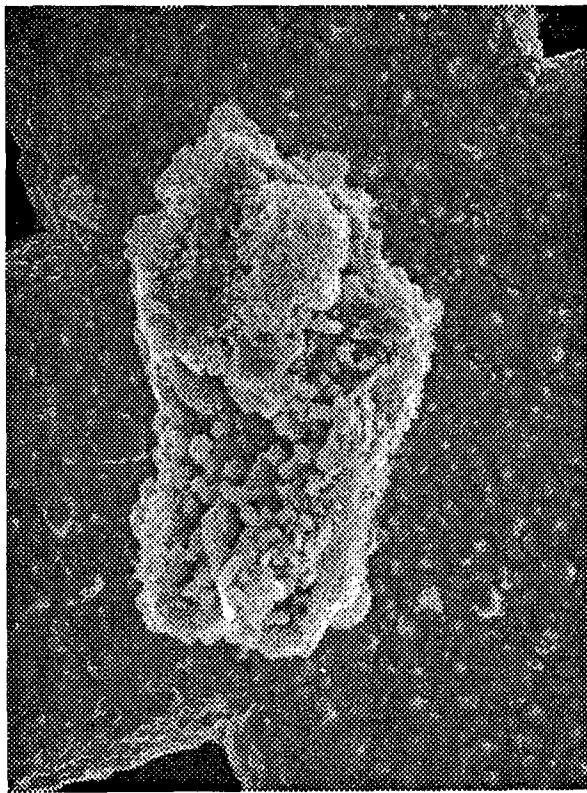
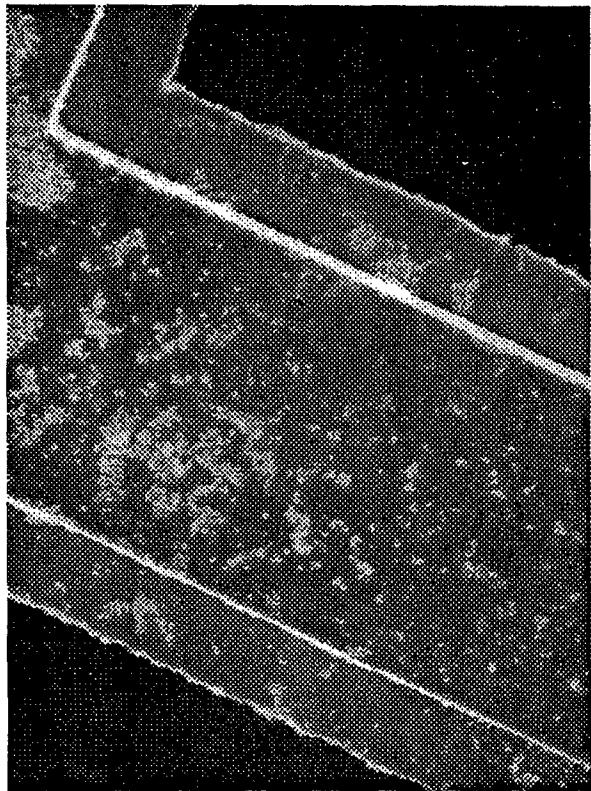
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*SHS Titanium Diboride (TiB_2) -
Alcoa-SG 1000 Alumina (Al_2O_3)*



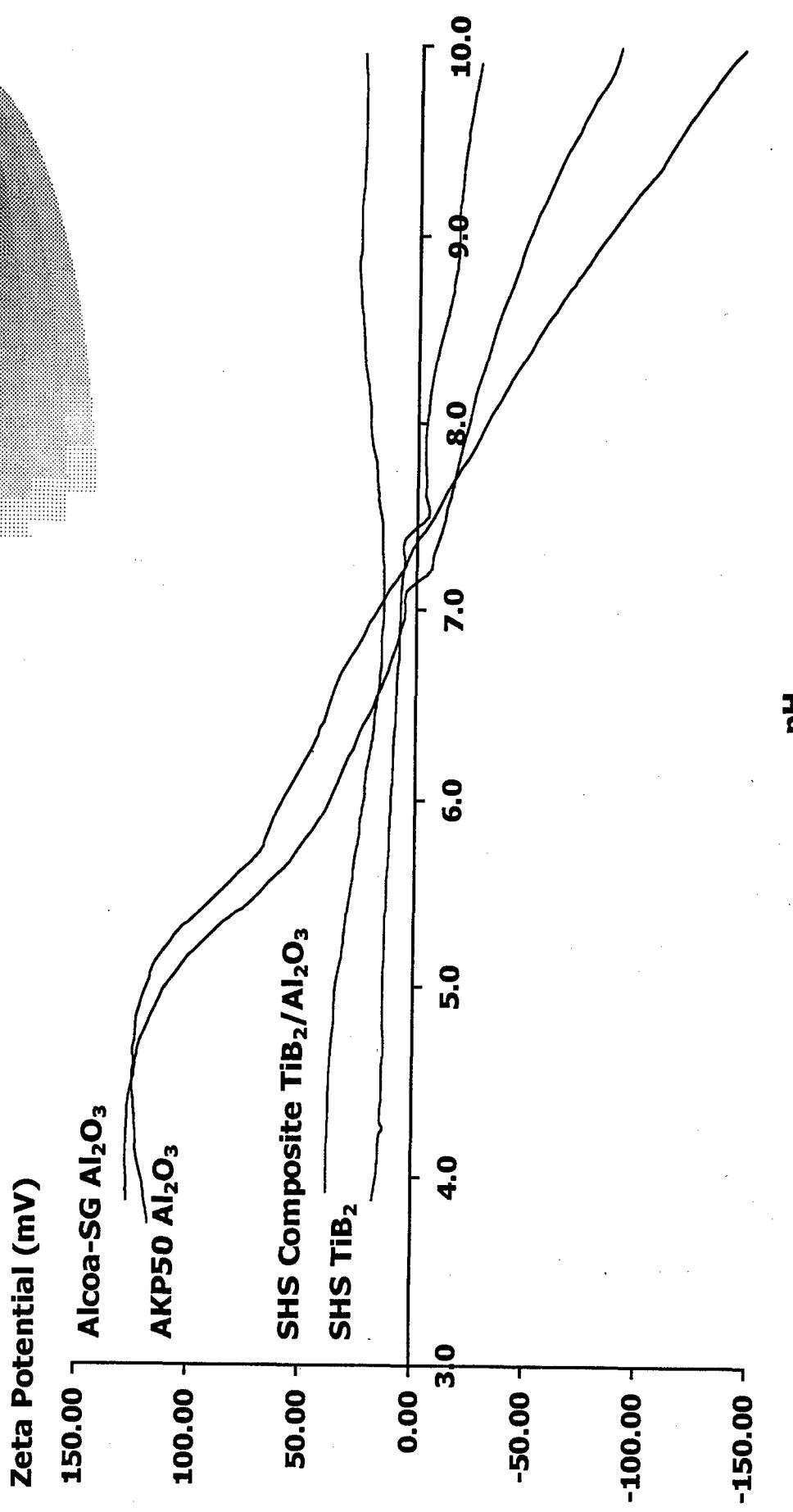
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*SHS Titanium Diboride (TiB_2) -
Sumitomo AKP50 Alumina (Al_2O_3)*



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Electrokinetic Sonic Analysis (ESA)

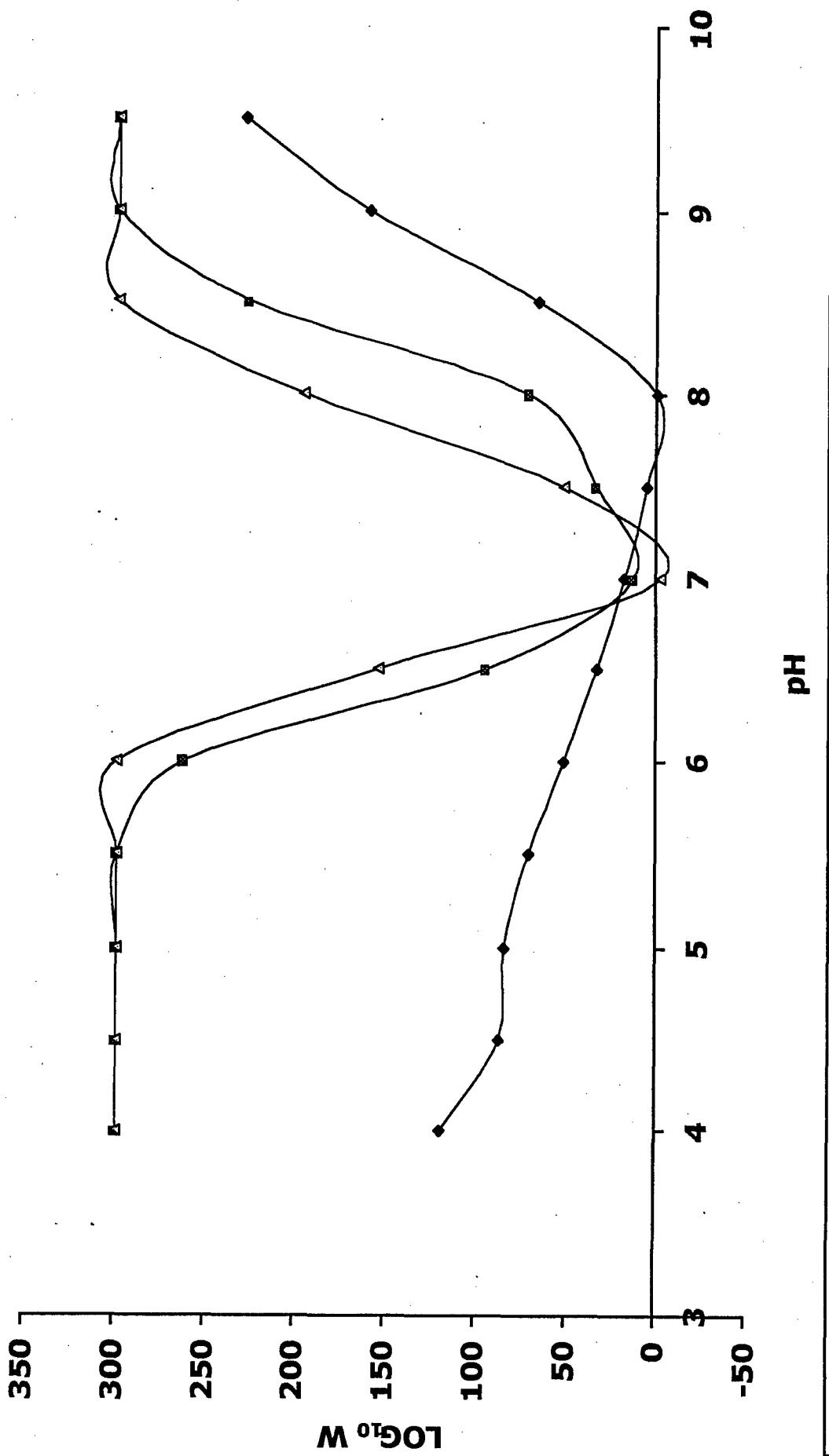


Suspension Stability[©] Predictions

| Stability Ratio W | SHS TiB ₂ / SHS TiB ₂ Interactions | SHS TiB ₂ / AKP50 Al ₂ O ₃ Interactions | AKP50 Al ₂ O ₃ / AKP50 Al ₂ O ₃ Interactions |
|------------------------------|--|--|--|
| Range of Predicted Stability | pH 4-6 and pH 8.5-9.5 | pH 4-6 and pH 8.5-9.5 | pH 4-7 and pH 8-9.5 |

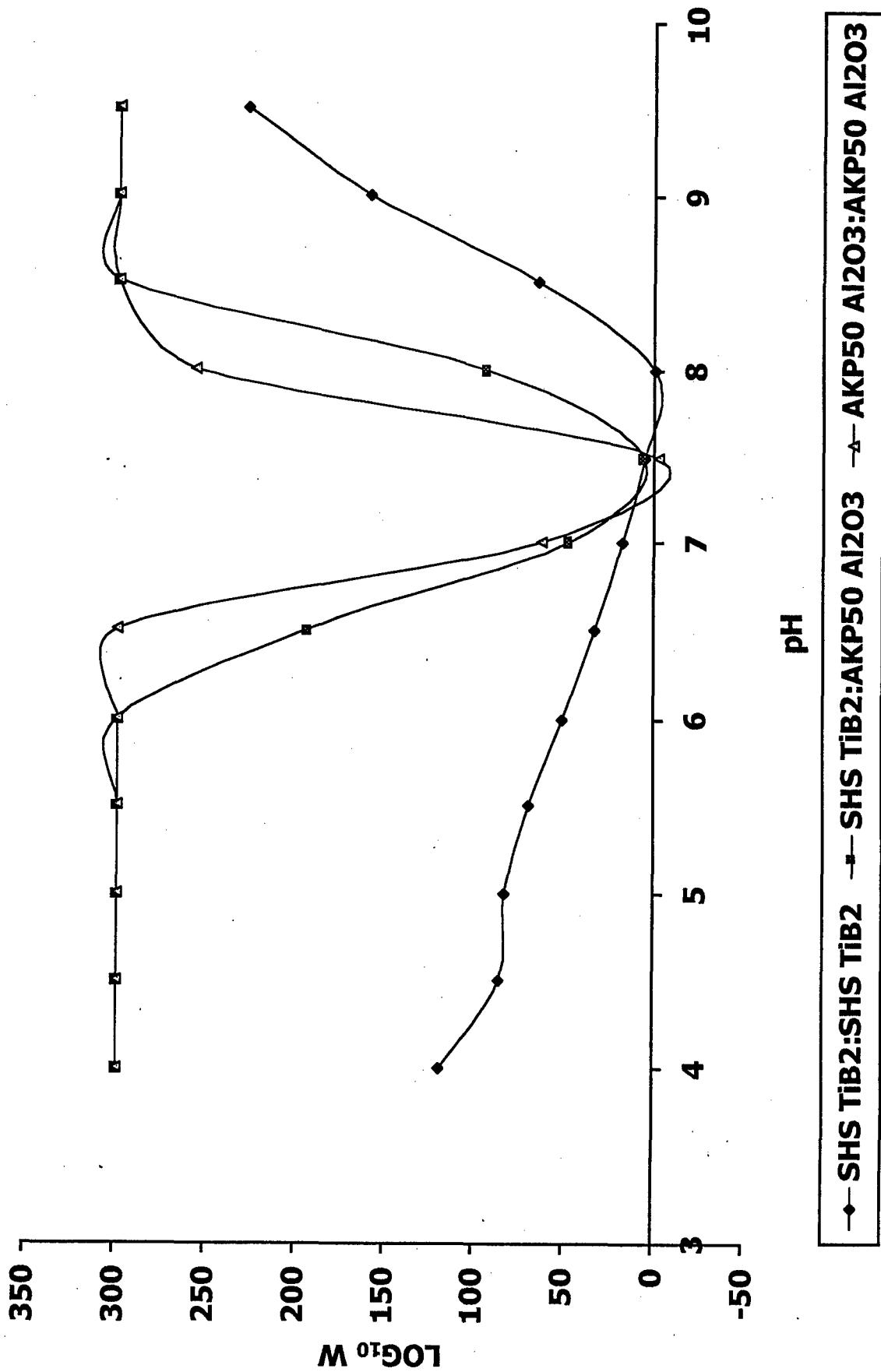
| Stability Ratio W | SHS TiB ₂ / SHS TiB ₂ Interactions | SHS TiB ₂ / Alcoa-SG Al ₂ O ₃ Interactions | Alcoa-SG Al ₂ O ₃ / Alcoa-SG Al ₂ O ₃ Interactions |
|------------------------------|--|---|--|
| Range of Predicted Stability | pH 4-6 and pH 8.5-9.5 | pH 4-6 and pH 8.5-9.5 | pH 4-6.5 and pH 7.5-9.5 |

Stability Ratio (W) Data
Titanium Diboride (SHS TiB₂) : Alumina (Alcoa-SG Al₂O₃)
Electrolyte Concentration 10⁻³M KNO₃



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 SHS TiB₂ : SHS TiB₂ SHS TiB₂:Al₂O₃ Alcoa-SG Al₂O₃

**Stability Ratio (W) Data
Titanium Diboride (SHS TiB₂) : Alumina (AKP50 Al₂O₃)
Electrolyte Concentration 10⁻³M KNO₃**



—♦— SHS TiB₂:SHS TiB₂ —△— SHS TiB₂:AKP50 Al₂O₃ —▲— AKP50 Al₂O₃:AKP50 Al₂O₃

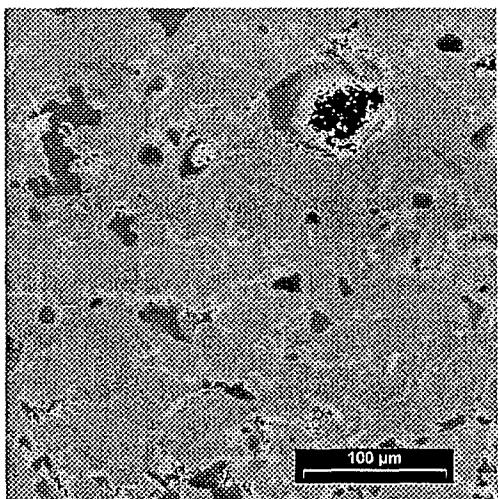
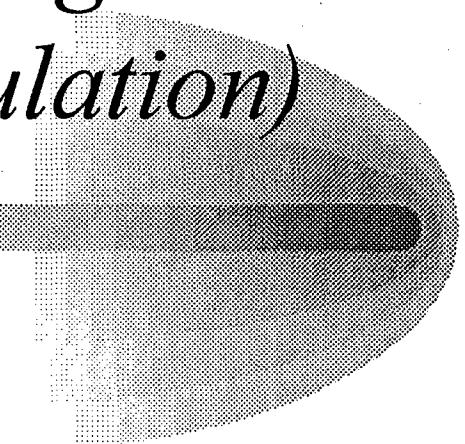
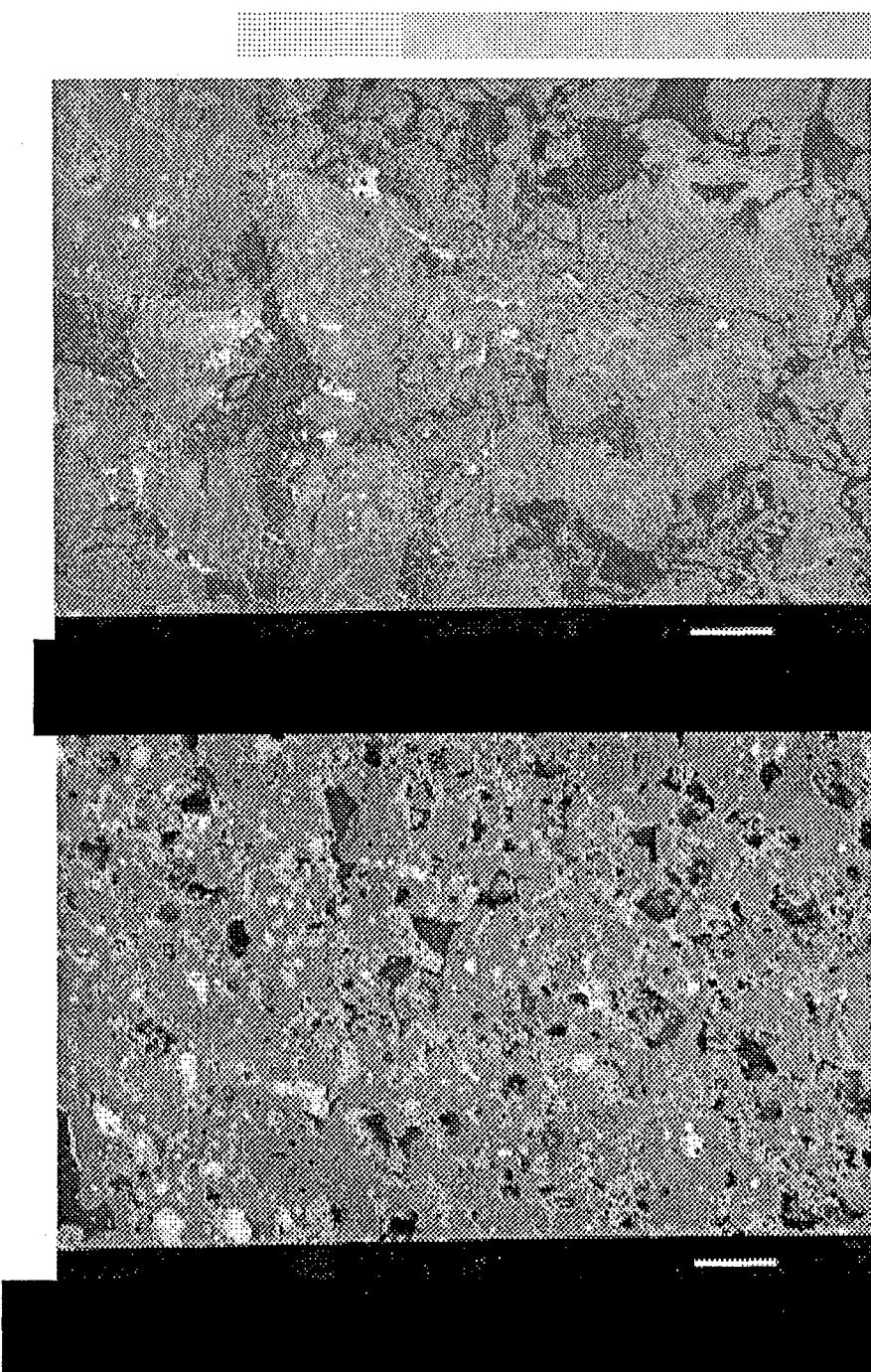
Processing Conditions

| Processing Conditions | SHS Composite TiB ₂ /Al ₂ O ₃ | SHS TiB ₂ / AKP50 Al ₂ O ₃ | SHS TiB ₂ / Alcoa-SG Al ₂ O ₃ |
|-----------------------|---|--|---|
| Traditional Binder | PEG | PEG | PEG |
| Dispersed | pH 4 | pH 4 | pH 4 |
| Coagulated | pH 7 | pH 7.5 | pH 7 |
| Heterocoagulated | pH 9 | pH 8 | pH 8 |

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PEG Binder

(no colloid processing - no influence on coagulation)

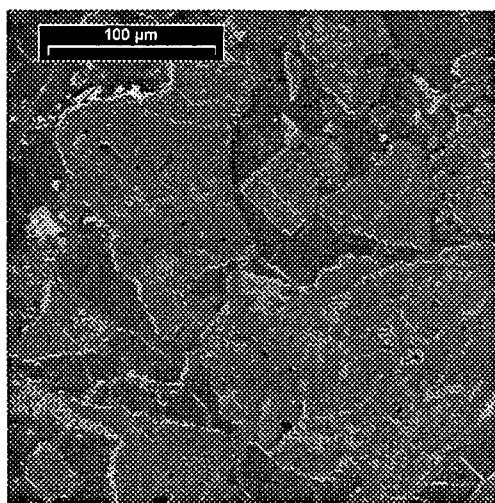


*SHS TiB_2 -
AKP50 Al_2O_3*

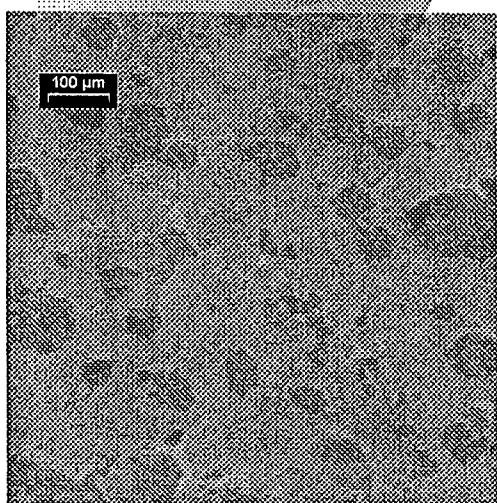
Dispersed Phases -

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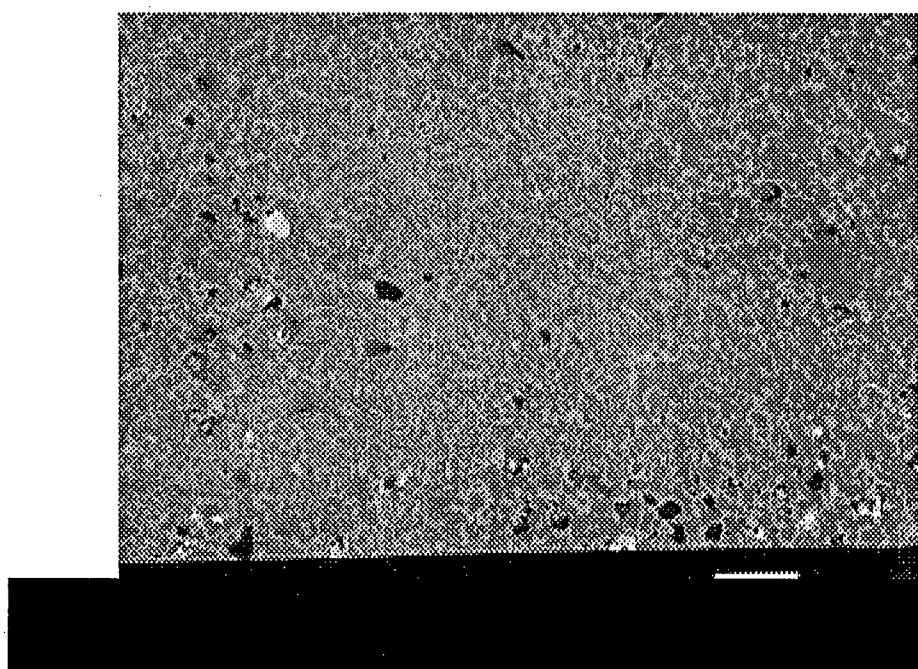
Low pH



SHS Composite



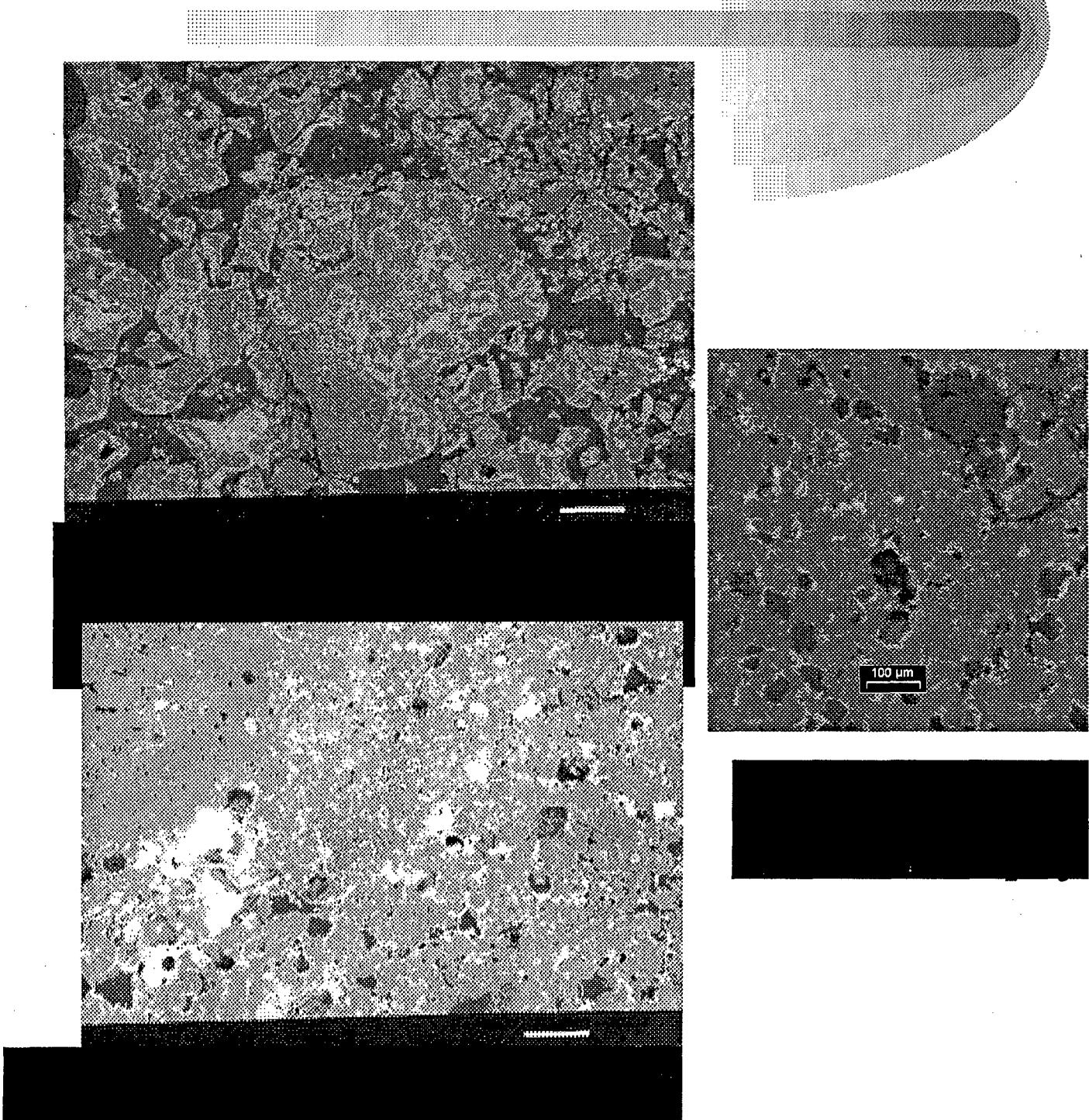
SHS TiB_2 - AKP50 Al_2O_3



Coagulated Phases -

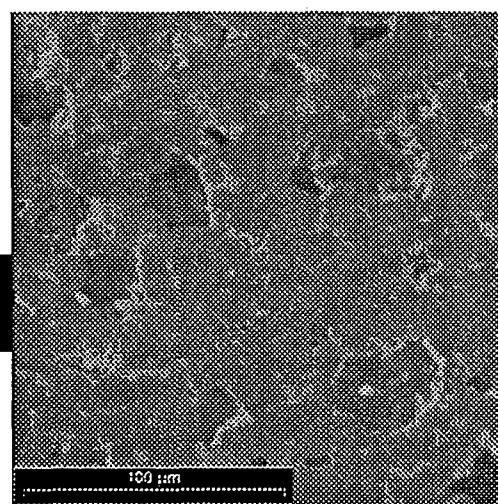
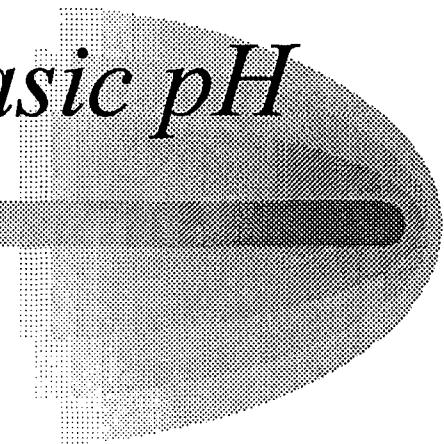
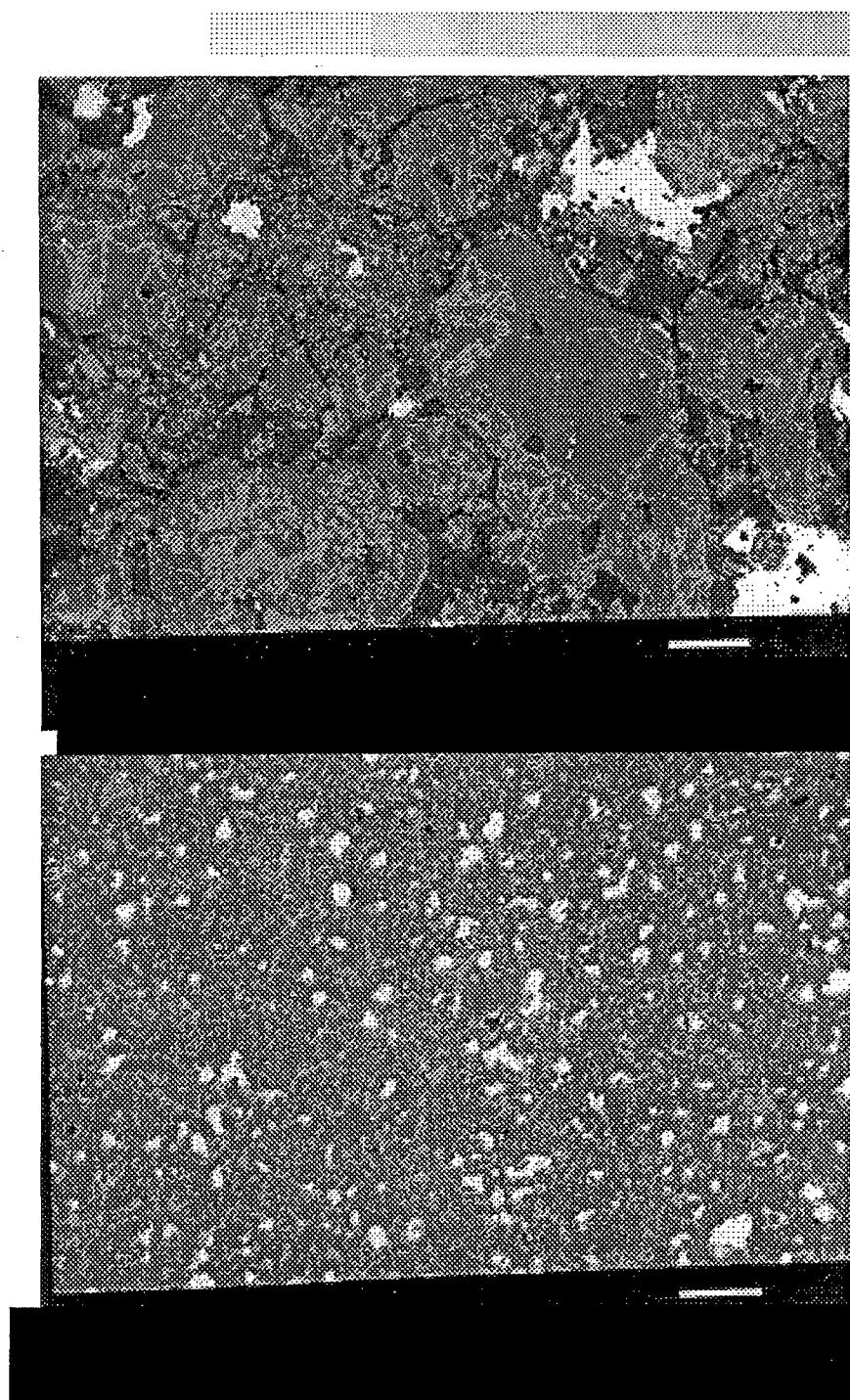
Neutral pH

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Heterocoagualted Phases -

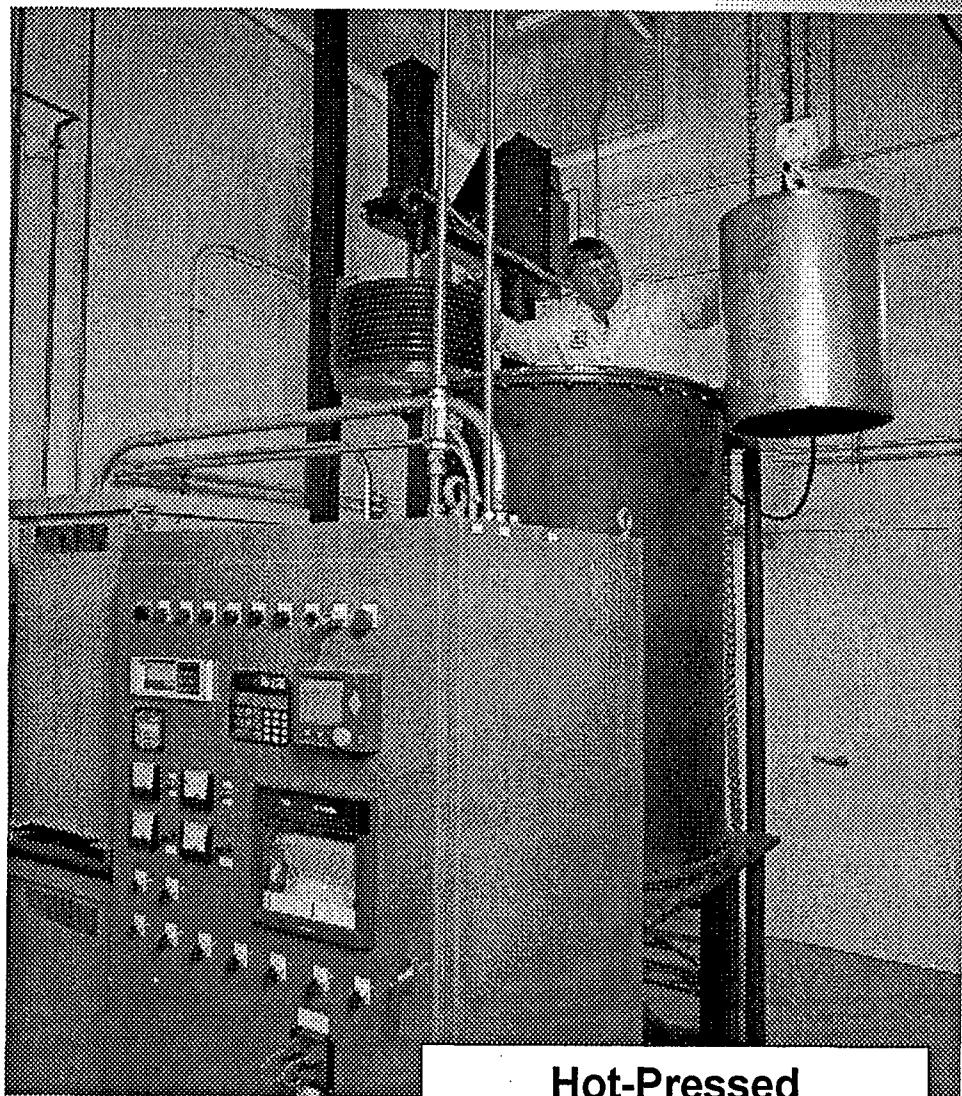
Basic pH



*SHS TiB_2 -
 $AKP50 Al_2O_3$*

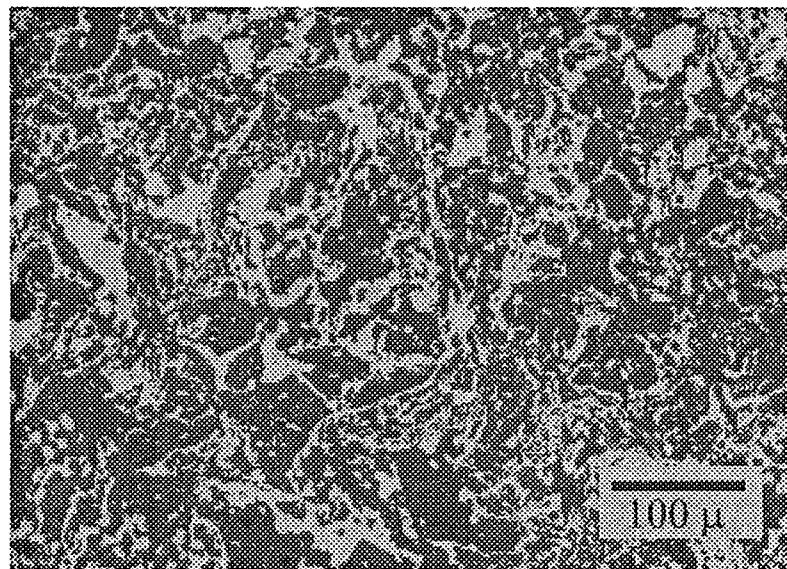
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Hot Isostatic Press



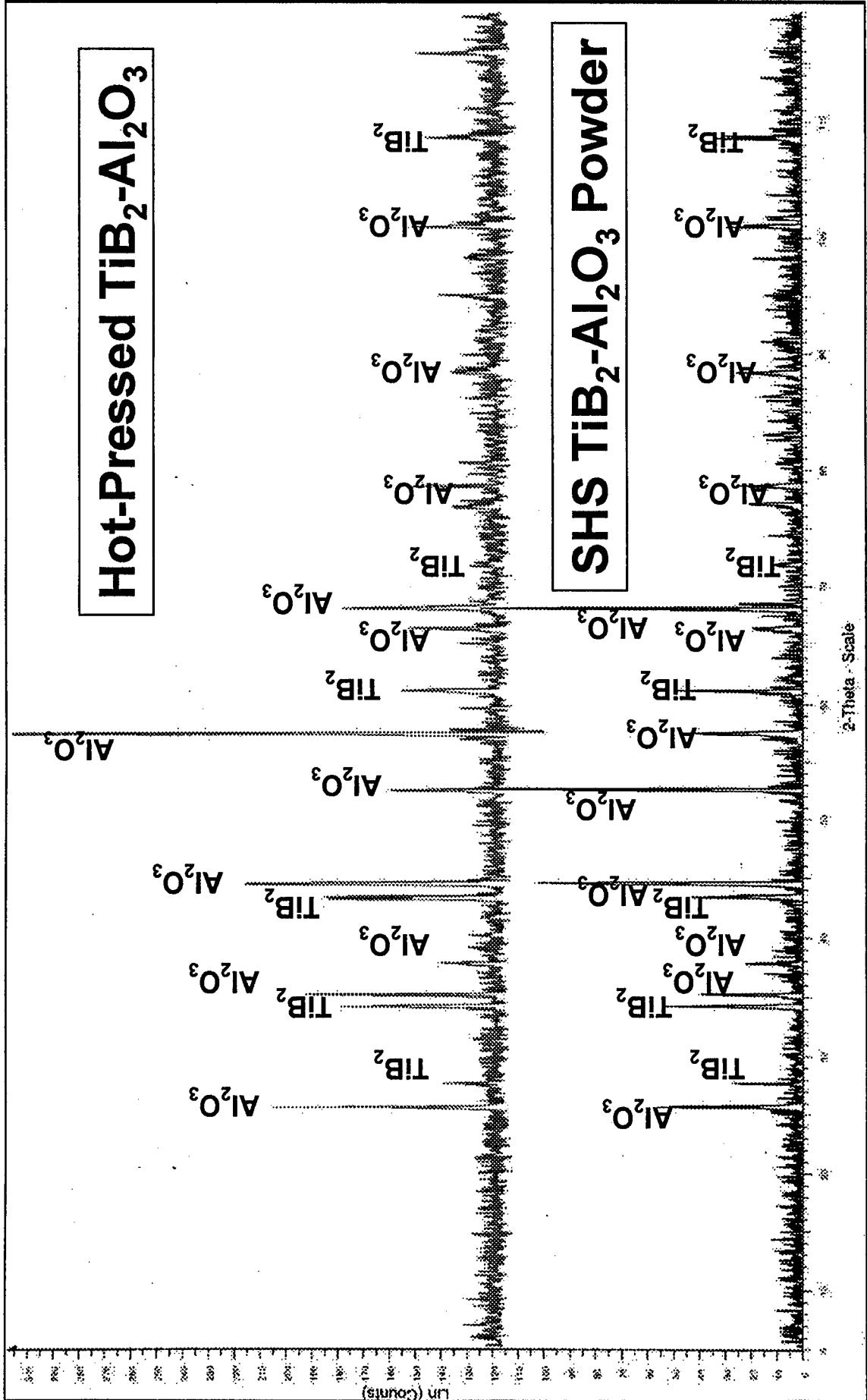
Hot-Pressed
4" Diam.
 $TiB_2 \cdot Al_2O_3$

Complete Densification



SHS Composite TiB₂-Al₂O₃

X-Ray Diffraction Patterns



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Conclusions

- SHS Composite TiB_2/Al_2O_3 powders are insensitive to colloidal processing and require HIP'ing for complete densification
- *Suspension Stability*[©] successfully predicted the behavior of SHS TiB_2 in Alumina
- The Continuous Microstructure is characteristic of SHS Composite TiB_2/Al_2O_3 starting powders

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Author/Originator(s): Lisa Prokurat Franks

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